Titanium

Metal Injection Molding

and

3D Binderjet Printing

TriTech TITANIUM PARTS

Desktop Metal

PMTi 2022 Powder Metallurgy and Additive Manufacturing of Titanium

Robert Swenson

TriTech Titanium Parts LLC

6401 East Seven Mile Road

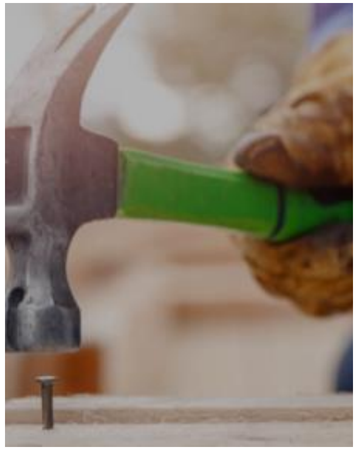
Detroit, Michigan, USA

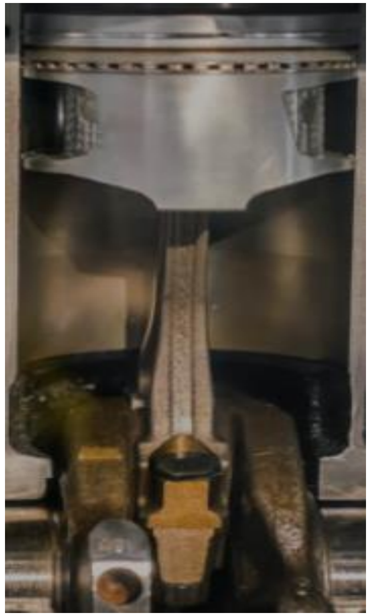
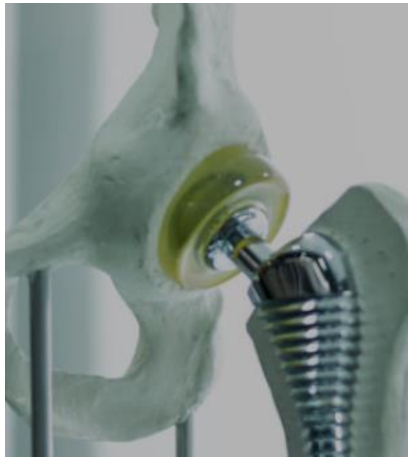
Robert Swenson is a 45-year veteran of the metals industry. With experience in HSLA, superalloys, specialty metals, and titanium. Robert was a graduate of Purdue University in Metallurgical Engineering and Harvard Business School with an MBA. Robert owned AmeriTi Manufacturing Company for 25 years and then sold it to Kymera International on April 5, 2022. At the same time, TriTech Titanium Parts was formed.

- **Victor Villarini**, Engineering Manger – TriTech Titanium Parts
- **Tim Daugherty**, Research Scientist – Desktop Metal/ExOne
- **Patrick Doughterty**, Dir of Commercial R&D – Desktop Metal/ExOne

Agenda

- About TriTech Titanium Parts
- About Desktop Metal / ExOne
- Processes … MIM and BJP
- Results … MIM and BJP
- Pros and Cons … MIM vs. BJP
- Next Objectives



TriTech Titanium Parts

- Located in Detroit, Michigan, USA.
- Operations for MIM and IC started in 2015 as a department of AmeriTi Manufacturing Company.
- AmeriTi was sold, and TriTech was a spin-off from AmeriTi in April 2022.
- Offering customers three technologies to find the best fit for the part.

<u>3D BINDERJET PRINTING</u> **<u>METAL INJECTION MOLDING</u>**

<u>INVESTMENT CASTING</u>

- Desktop Metal P1 printer commissioned on July 18, 2022.

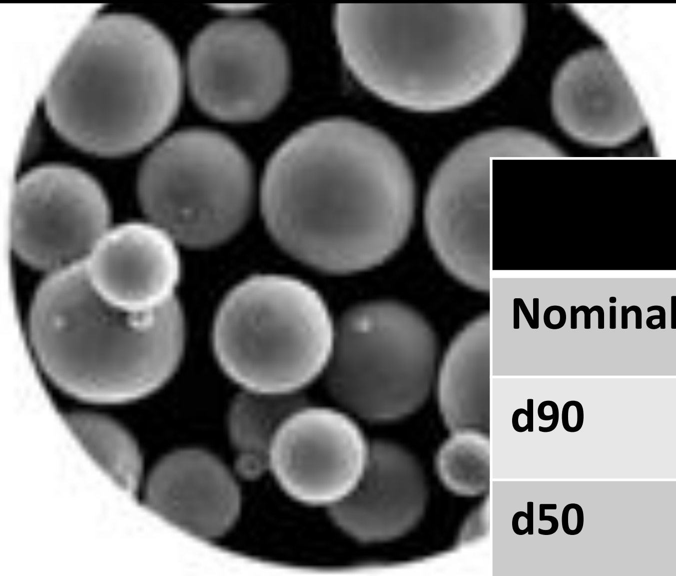
Desktop Metal / ExOne

- Industry leader Desktop Metal headquarters in Burlington, Massachusetts, USA.
- ExOne is a secondary location in North Huntingdon, Pennsylvania, USA.
- Manufacturing a broad line of Additive Manufacturing technologies.
- 3D Binderjet Printing is offered to all industries and materials.
- All materials ….. sand, refractories, wood, plastic, and metal.
- Also, printers for plastic.
- Heavy R&D for materials and process development.
- Inert binderjet printing for reactive materials – aluminum and titanium.

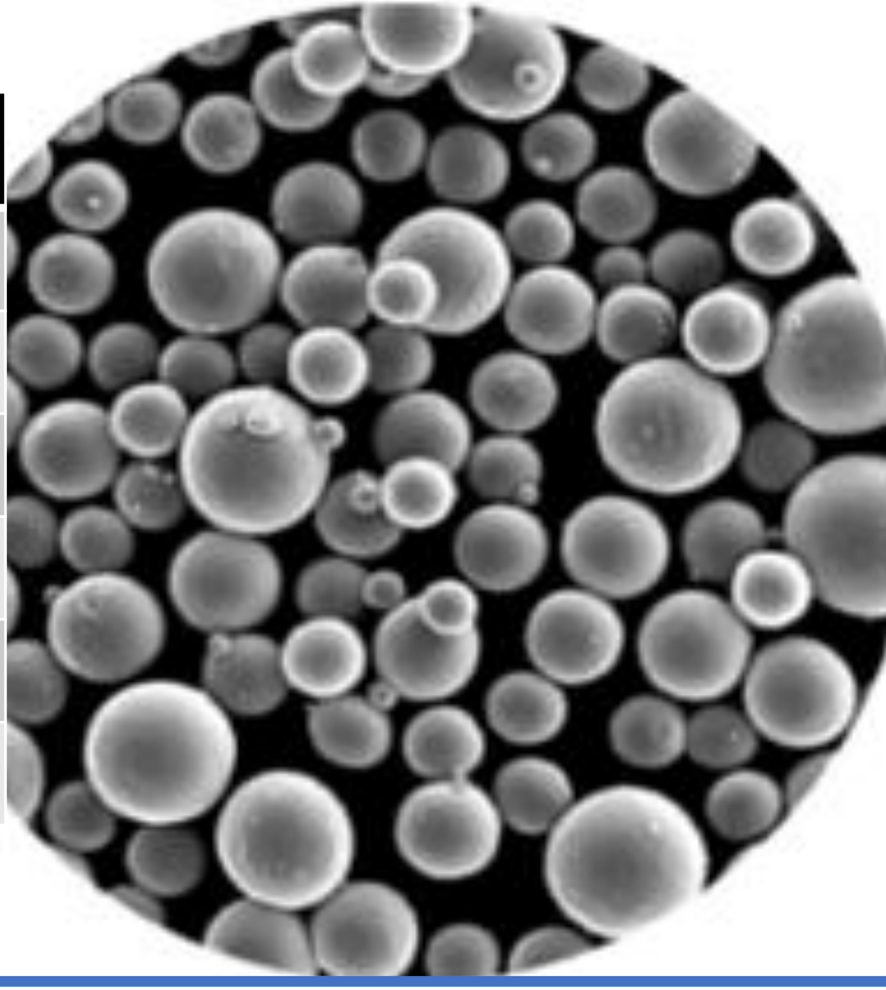
Joint Effort – TriTech and Desktop Metal

- Work began in 2021 for development of binderjet printing for titanium.
  - Print settings, binder, and thermal cycle.
  - To improve O_2 content, C content, density, and mechanical properties.
- Printed test coupons and sample parts with the ExOne Innovent.
- Thermal debind and sintering at TriTech with Elnik vacuum sintering furnace.
- For the powder; started with eight different spherical powders.
  - The d10, d50, and d90 are all important.
  - C and O_2 are important to start low.

Powder Characteristics



	A	B	C	D
Nominal	25 x 5	20 x D	45 x 15	45 x D
d90	24	17	48	48
d50	14	12	33	32
d10	7	5	20	9
O_2	.12%	.18%	.11%	.13%
C	.007%	.010%	.008%	.020%

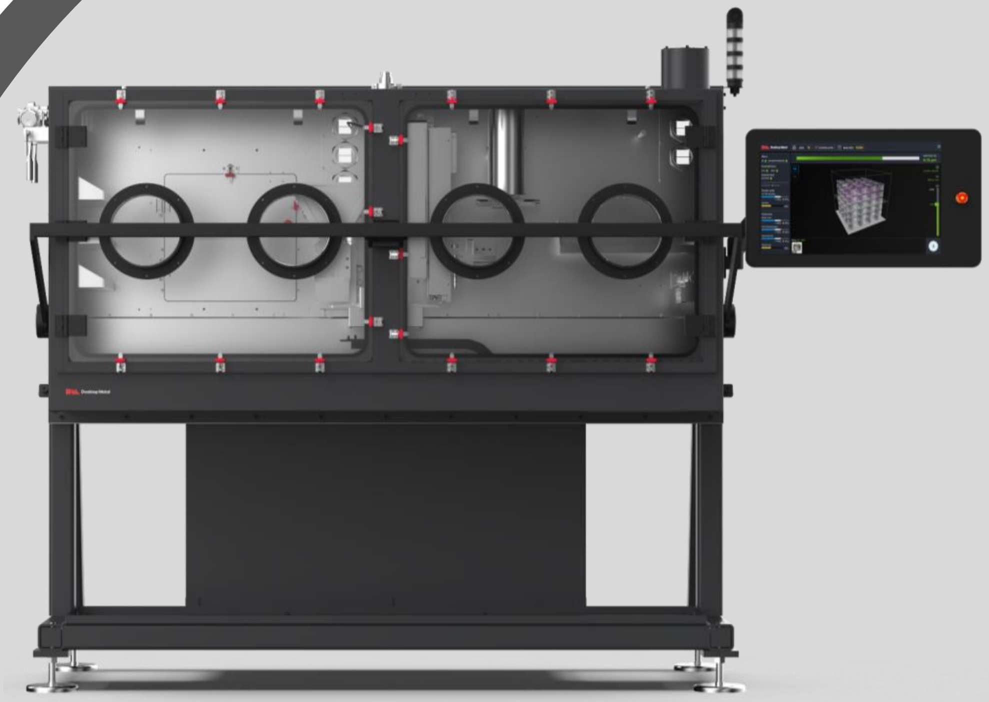


Metal Injection Molding

- **Ti metal powder is mixed with organic binder.**
- **The feedstock is injected into die (the part).**
- **Solvent debind to remove the first ½ of the binder.**
- **Into the ELNIK vacuum sintering furnace.**
- **Thermal debind to remove the second ½ half of the binder.**
- **Sintering at 2,300 to 2,400ºF with Ar purge.**

3D Binderjet Printing

- Free-flowing Ti metal powder.
- 50 um layers in the build box, inert atmosphere.
- Printhead deposits the binder (the glue).
- The glue is cured in a low temperature oven. Then de-powder the excess.
- Into the ELNIK vacuum sintering furnace.
- Thermal debind for removal of the binder.
- Sintering at 2,300 to 2,400ºF with Ar purge.



Process Comparison

Metal Injection Molding

Solid Model	Tool / Die Production	Injection	Solvent Debind	Thermal Cycle for Debind and Sinter
	2 to 5 months	1/2 day	1/2 day	1 day

Binderjet Printing

Solid Model	Predict Shrink	Printing	Curing and De-Powder	Thermal Cycle for Debind and Sinter
	2 to 5 days	1/2 day	1/2 day	1 day

MIM vs. BJP – Shrink

MIM

- The green density is 64% by volume.
- Parts shrink 14% each direction.
- Sintered density at 98 to 99% (no HIP).
- Established process.

- The injection is isotropic.
- The packing is uniform.
- Shrink is the same in all directions.

BJP

- The green density is 54% by volume.
- Parts shrink about 20% each direction.
- Sintered density at 95 to 97% (no HIP).
- New process.

- The layers are deposited in the X direction.
- The building of the layers in the Z direction.
- Shrink varies with X, Y, Z directions.

✓ The difference in green density = the difference in shrink.

✓ Injection packing > printer packing.

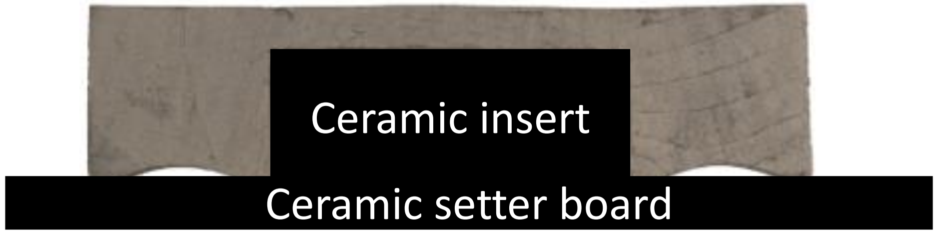
Desktop Metal … P1 Printer

- The Binderjet process … lots of variables for print optimization.
- Nesting of parts.
- Layer thickness.
- Print head settings.
- Binder saturation.

- The next issue is to control shrink and distortion.
- Variation in X, Y, and Z directions.
- It is predictable and repeatable.

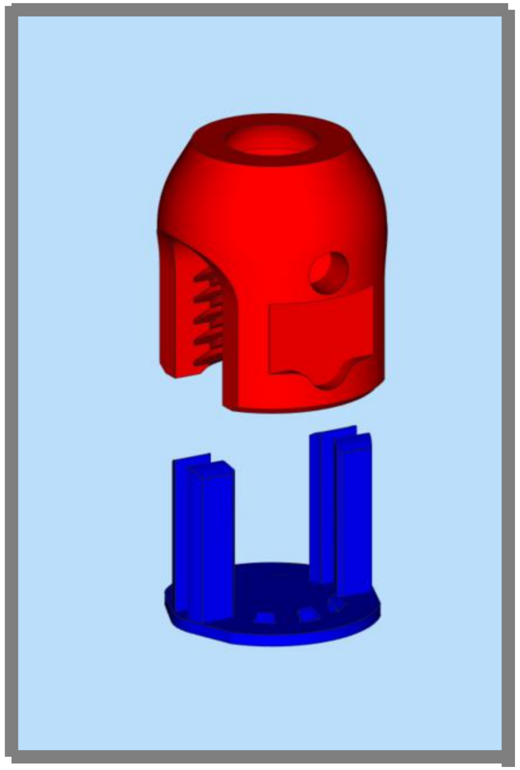
Shrink and Distortion

- 1st Option – Ceramic Setter
  - While sintering, there can be distortion.
  - Such as the sagging bridge.
  - The part can land on a ceramic setter.
  - Cost of machining the setter.
  - Common solution for MIM.
  - Works for BJP too.



Shrink and Distortion

- 2nd Option – Live Setter
  - While printing, a second part is printed as a live setter for the target part.
  - While sintering, the target part will shrink with the printed live setter.
  - Increases the cost of the part (almost 2 parts).
  - Less expensive than ceramic setter.
  - Good for low volume and high complexity.
  - Ideal for BJP.

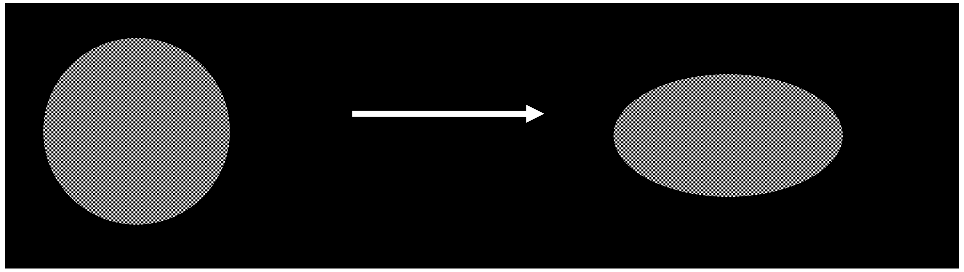


Shrink and Distortion

- **3rd Option – Live Sinter**
  - A Desktop Metal solution.
  - Print a 1st iteration. Round hole becomes oval.
  - Scan the results and adjust the solid model.
  - Print a 2nd iteration. Oval hole becomes round.
  - Making adjustments to the solid model to print an accurate part.
  - The program can learn and be predictive.
  - Great tool to manage shrink and distortion.

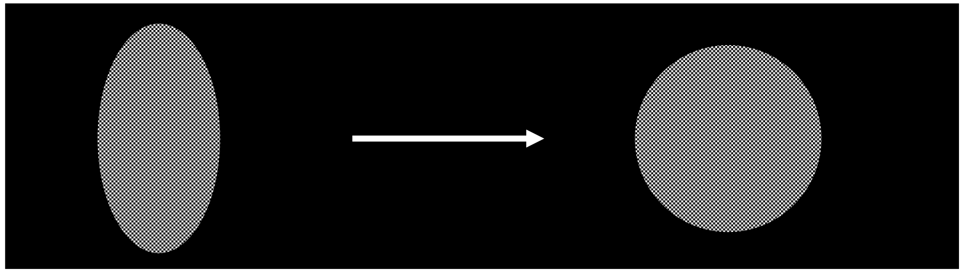
1st Iteration

sintered



2nd Iteration

sintered



MIM vs. BJP … Properties

	MIM w/o HIP	BJP w/o HIP	ASTM F 2885 (MIM spec)
Surface (um)	1	7	--
TS (MPa)	1,050	1,000	780 min
YS (MPa)	980	915	680 min
E	11%	10%	10% min
RA	15%	15%	15% min
C	.03%	.06%	.08%
O_2	.17 to .23%	.19 to .25%	.20%
Density (%)	98 to 99	95 to 97	--

MIM vs. BJP vs. IC … PROs and CONs

	MIM	BJP	IC
Surface Roughness	★★★	★	★★
Tooling	★	★★★	★★
Part Cost	★★★	★★	★
Low Volume	★	★★★	★★
Part Complexity	★★	★★★	★
Ease of Prototype	★	★★★	★★
Part Size	★	★★	★★★
Speed to Market	★	★★★	★★
Custom Features	★	★★★	★

BJP … Next Objectives

Binder
- Binder precision.
- Green strength.
- Chemistry.

Powder
- d10, d50, and d90.
- Lower O_2 content.
- Surface chemistry.
- Multi-modal powders.

Thermal Cycle
- Meeting .20% max for O_2.
- Lower C, <.08%.

Sintering
- Time and temperature.
- Sintered density.
- Properties.

Robert Swenson
TriTech Titanium Parts LLC
6401 East Seven Mile Road
Detroit, Michigan 48234
(248) 561-8510
rswenson@tritechtitanium.com